Scientific Research Report

Effect of Mouthwashes for COVID-19 Prevention on Surface Changes of Resin Composites

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A B S T R A C T

Objective: The aim of this research was to investigate the effect of various mouthwashes for COVID-19 prevention on surface hardness, roughness, and colour changes of bulk-fill and conventional resin composites and determine the pH and titratable acidity of mouthwashes.

Methods: Four hundred eighty specimens were fabricated in cylindrical moulds (10 mm in diameter and 2 mm in thickness). Before immersion, baseline data of surface hardness, roughness, and colour values were recorded. Each product of specimens (Filtek Z350XT, Premise, Filtek One Bulk Fill Restorative, SonicFil 2) were divided into 4 groups for 0.2% povidone iodine, 1% hydrogen peroxide, 0.12% chlorhexidine, and deionised water (serving as a control). The specimens were immersed in mouthwashes for 1 minute and then stored in artificial saliva until 24 hours. This process was repeated for 14 days. After immersion, surface hardness, roughness, and colour values of specimens were measured at 7 and 14 days. The data were statistically analysed by 2-way repeated analysis of variance, Tukey honestly significant difference, and t test ($P < .05$).

Results: After immersion, all mouthwashes caused significantly lower surface hardness and greater roughness and colour values ($P < .05$) on all resin composites tested.

Conclusions: Mouthwashes had an effect on all resin composites evaluated leading to a significant decreased surface hardness and an increased roughness and colour values ($P < .05$).

Introduction

COVID-19 is an infection casued by a single-stranded RNA virus belonging to the coronavirus family.[1] The virus has spike proteins located on the infected surface binding to the angiotensin-converting enzyme 2 receptor that is found in mucous tissues, gingiva, the epithelium of the tongue, and salivary glands.[1,2] During an infection the highest number of viral paricles will be found in the nasopharynx and the oro-pharynx, and possibly sputum.[3,4] This implies that COVID-19 has is a professional hazard to dentists who are regularly exposed to the aerosols from the oral cavity.[5] Therefore, before starting any dental procedure, the patient is usually asked to rinse and spit out a disinfectant mouthwash (such as 0.2% povidone iodine) by gargling for 1 minute and then spitting out. Povidone iodine is contraindicated in patients with abnormal thyroid function or with a history of iodine allergy, patients with kidney disease, pregnant patients, patients during lactation, and children younger than 6 years. On the other hand, an alternative disinfectant such as one percent hydrogen peroxide may cause quite high irritation; therefore, it should not be used in the elderly; people with dry mouth, little saliva, or mouth ulcers; and patients who have had a tooth extracted. A third mouthwash, Chlorhexidine, 0.12% concentration, causes irritation in patients who are unable to control swallowing, such as paediatric patients or elderly patients. Thus, using gauze or a cotton swab moist-ened with mouthwash to wipe the inside of the mouth is a better option than a spitting solution.[6,7]

MOUTHWASHES FOR COVID-19 PREVENTION

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However, in addition to the benefits mentioned, using mouthwash may have side effects on oral tissues and restorative materials.[8-10] Bulk-fill resin composite has greater colour changes than that of the nanohybrid resin composite.[8] However, resin composite has the least colour change compared to compomer, giomer, and resin-modified glass ionomer cement.[9] One study has also compared the colour change and surface destruction of bulk-fill resin composites after immersion in 0.05%, 0.1%, and 0.12% chlorhexidine mouthwash. The results have showed that 0.1% chlorhexidine mouthwash caused the most discolouration and surface damage.[10] Chlorhexidine mouthwash causes a brown staining on tooth surfaces, resin composite, and other restorative materials.[11] For this reason, mouthwash concentration is controlled; for example, povidone iodine mouthwash should be used at a concentration lower than 2.5% for safe, routine use.[4]

A number of studies present the degradation of resin composites from drinks, beverages, and also mouthwashes.[12−24] However, there were no comparative studies of changes in surface hardness, surface roughness, and colour of bulk-fill and conventional nanohybrid and nanofill resin composites resulting from preoperative disinfectant mouthwash used for prevention of COVID-19. Therefore, the aims of this study were to investigate the effects of various mouthwashes for COVID-19 prevention including 0.2% povidone iodine, 1% hydrogen peroxide, and 0.12% chlorhexidine on surface hardness, surface roughness, and colour changes of bulk-fill and conventional nanohybrid and nanofill resin composite materials and to study the pH and titratable acidity of various disinfectant mouthwashes. This study tested the research hypothesis that surface hardness, roughness, and colour changes of resin composites tested would change after immersion in different mouthwashes for COVID-19 prevention.

Methods

Specimen preparations

The resin composite materials used in this study and their composition are shown in Table 1. The sample size of this study was calculated using mean and standard deviation values from a previous study[8] by a sample size calculation programme where α = 0.05 and power = 0.8 (G*Power version 3.1.9.5, Heinrich-Heine-Universität Düsseldorf).[25] At least 10 samples were allocated for each group.

A total of 480 samples were prepared: 120 specimens per each material product. The material was filled in a polytetrafluoroethylene mould, 10 mm in diameter and 2 mm in thickness,[9,26] and placed on a glass slip. Then the material was covered with a mylar matrix strip and another glass slip covered over that. A static load of approximately 20 N was placed over the glass slip to remove excess material and obtain a smooth surface. An LED light curing unit (Elipar DeepCure-S LED Curing Light, 3M ESPE) was used to polymerise the material for 20 seconds.[12] A measuring device (Cure Rite, L.D. Caulk) was used to verify the light intensity (1422.81 $\pm$ 4.19 mW/cm^2). After polymerisation, the mylar strip and the glass slips on the top and bottom of the mould were removed. No polishing of the specimens were performed.

Mouthwash preparations

The mouthwashes used were povidone iodine (Thai Meiji Pharmaceutical, Lad Krabang), hydrogen peroxide (Vidhyasom, Wattana), and chlorhexidine (Osoth Inter Laboratories). A new preparation of each mouthwash was prepared every day for 14 days. 0.2% povidone iodine was prepared from 10.3 mL of 7% povidone iodine, and distilled water was added to a volume of 360 mL. One percent hydrogen peroxide was prepared from adding distilled water into 120 mL of 3% hydrogen peroxide until the total volume was 360 mL.

The pH and titratable acidity measurement

A pH meter (SevenCompact pH meter) was used to measure the pH of each mouthwash. Then, 1.5 mL of 1 mol/L sodium hydroxide (NaOH) was added to 20 mL of each mouthwash until reaching pH levels of 5.5, 7, and 10, respectively, for titration[27−29] and the volume amount of NaOH used was recorded. The mean volume of NaOH used for titration of each mouthwash was obtained from 10 repetitions.

Mouthwash immersions

Four products of prepared resin composite specimens, 120 specimens per each product, were divided into 4 groups for each mouthwash (0.2% povidone iodine, 0.1% hydrogen peroxide, and 0.12% chlorhexidine) and deionised water (serving as the control), with 30 specimens per group. Before immersion, surface hardness, roughness, and colour values were measured for baseline data.

The specimens were immersed in 25 mL of mouthwash for 1 minute and then stored in artificial saliva (changed daily) and kept overnight at 37 °C until 24 hours. This process was repeated for 14 days. The specimens were placed upright in a rack where both sides of the specimen were immersed in the mouthwash at the same time. The mouthwashes were changed daily during the experiment to obtain the original pH value of the mouthwashes. After the immersion sequence was completed, the specimens were rinsed with deionised water, blotted dry, and subjected to surface hardness, roughness, and colour value testing at intervals of 7 and 14 days.

Surface hardness testing

Surface Vickers hardness of each specimen was measured using a microhardness tester (Micromet II, Buehler) with a Vickers diamond indenter; 0.3 N force was applied on the top surface of the specimen for 10 seconds. Five indentations were made on the surface of each specimen equally spaced around a circle. Mean hardness values (kg/mm^2) before and after immersions (on days 7 and 14) were calculated and recorded.

Surface roughness testing

A profilometer (Surfcorder model SE-2300, Kosaka Laboratory Ltd.) was used to measure the surface roughness. The traversing distance of the stylus was 4 mm, and the radius of the tracing diamond tip was 5 μm. The cutoff was 0.8 mm and the

Table 1 – Resin composite materials evaluated in the study.

Material	Type	Composition		Filler size, nm	Filler by volume, %	Manufacturer
		Matrix	Filler			
Filtek Z350 XT	Nanofilled	UDMA, Bis-EMA, TEGDMA, PEGDMA	Silica, zirconia	20, 4-11	63.3	3M ESPE
Premise	Nanohybrid	Bis-EMA, UDMA, TEGDMA	Prepolymerised filler barium glass	400	69	Kerr Corp.
Filtek One Bulk Fill Restorative	Nanofilled (bulk fill resin composite)	AFM, AUDMA, DDDMA, UDMA	Silica, zirconia, ytterbium trifluoride, Zirconia/silica cluster	20, 4-11, 100, 20 nm silica/4-11 nm zirconia	58.4	3M ESPE
SonicFil 2	Nanohybrid (bulk fill resin composite)	Bis-EMA, TEGDMA	Zirconsil (zirconium + silica oxide), ytterbium trifluoride	400	69	Kerr Corp.

AFM, addition fragmentation monomers; AUDMA, aromatic urethane dimethacrylate; Bis-EMA, ethoxylatedbisphenol-A dimethacrylate; DDDMA, 1, 12-dodecanediol dimethacrylate; PEGDMA, polyethylene glycol dimethacrylate; TEGDMA, triethyleneglycoldimethacrylate; UDMA, urethane dimethacrylate.

measuring force and speed were 4 mN and 0.5 m/s, respectively. The Ra, the arithmetical average of the surface heights, of each specimen was recorded in 5 different positions (1.5 mm apart) and calculated to find a mean value before and after immersion (on days 7 and 14) in the mouthwashes.[24]

Colour measurements

For colour measurement, a spectrophotometer (ColorQuest XE, Hunter Associates Laboratory Inc.) was used for assessing the Commission Internationale de l'Eclairege L*a*b* (CIELAB) colour. Whereas L* indicates the lightness of the colour measured from black (L* = 0) to white (L* = 100), a* determines the colour in the red (a* > 0) and green (a* < 0) dimension, and b* determines the colour in the yellow (b* > 0) and blue (b* < 0) dimension. Five measurements were obtained from each specimen and were calculated for the mean L*, a*, and b* values. Overall colour change (ΔE*) was calculated using the following equation: $\Delta E^* = ([\Delta L^*]^2 + [\Delta a^*]^2 + [\Delta b^*]^2)^{1/2}$. The mean difference of ΔE* values for each group was calculated between baseline and after immersion on days 7 and 14. The resulting colour change was interpreted as follows: if ΔE* is less than 1, it indicates that it is indistinguishable to the human eye; a ΔE* value of less than 3.3 indicates that it can be distinguished by the eye of the operators but considered clinically acceptable; and ΔE* values of greater than 3.3 shows that they can be distinguished by the eyes of nonskilled persons and therefore are clinically not acceptable.[9]

Statistical analysis

After testing the normality with Shapiro−Wilk test, the mean values for surface hardness, roughness, and colour values were subjected to 2-way repeated analysis of variance, Tukey honestly significant difference, and a t test for multiple comparisons. The level of significance was set at $\alpha = 0.05$.

Results

The mean pH and titratable acidity of mouthwashes are shown in Table 2. The mean pH of 0.2% povidone iodine was the lowest, followed by 1% hydrogen peroxide and 0.12% chlorhexidine. For titratable acidity, the highest volume used of NaOH was found in 0.2% povidone iodine, followed by 1% hydrogen peroxide and 0.12% chlorhexidine.

The surface hardness, roughness, and colour change (ΔE*) values of the resin composites tested before and after immersion are presented in Tables 3, 4, and 5. Generally, amongst the 3 mouthwashes, the most significant decrease in surface hardness, increase in roughness, and the most colour changes of resin composites were found in the povidone iodine groups (P < .05). Amongst the 4 types of resin

Table 2 – Mean pH (± SD) and titratable acidity (indicated as volume of NaOH in mL) required adjust the pH levels (to 5.5, 7.0, and 10.0) of the evaluated mouthwashes.

Mouthwash	pH	Cumulative volume of NaOH solution used to titrate to:		
		pH 5.5	pH 7	pH 10
Povidone iodine	3.30 ± 0.04	12.12 ± 1.38	4.95 ± 0.79	24.12 ± 9.97
Hydrogen peroxide	4.12 ± 0.05	1.48 ± 0.50	2.08 ± 0.62	11.72 ± 1.55
Chlorhexidine	6.07 ± 0.12	1.21 ± 0.41*	0.87 ± 0.70	7.56 ± 0.94

* Titrated with Hydrochloric acid due to the original pH being alkaline.

Table 3 – Mean surface microhardness (± SD) of evaluated materials after immersion in various mouthwashes for different time periods

Material	Mouthwash	Mean surface hardness (kg/mm^2) ± SD		
		Before immersion	7 days after immersion	14 days after immersion
Filtek	Deionised water	85.87 ± 0.94	84.98 ± 0.75[a,A]	84.25 ± 0.80[a,A]
Z350XT	Povidone iodine	85.47 ± 0.55	79.05 ± 0.77[*,d,D]	77.03 ± 0.61[*,d,D]
	Hydrogen peroxide	86.10 ± 0.69	81.94 ± 0.39[*,c,C]	79.73 ± 0.38[*,c,C]
	Chlorhexidine	86.29 ± 0.49	83.52 ± 0.05[*,b,B]	81.46 ± 0.32[*,b,B]
Premise	Deionised water	60.75 ± 0.71	59.77 ± 0.64[a,A]	59.53 ± 0.74[a,A]
	Povidone iodine	60.87 ± 0.50	50.01 ± 0.71[*,d,M]	47.14 ± 0.44[*,d,M]
	Hydrogen peroxide	60.73 ± 0.50	52.81 ± 0.64[*,c,L]	50.56 ± 0.60[*,c,L]
	Chlorhexidine	60.75 ± 0.83	55.18 ± 0.74[*,b,K]	53.94 ± 0.63[*,b,K]
Filtek One	Deionised water	69.69 ± 0.33	68.80 ± 0.38[a,A]	68.02 ± 0.31[a,A]
Bulk Fill	Povidone iodine	69.57 ± 0.78	59.93 ± 0.56[*,d,G]	56.73 ± 0.59[*,d,G]
Restorative	Hydrogen peroxide	69.74 ± 0.43	62.24 ± 0.72[*,c,F]	59.95 ± 0.64[*,c,F]
	Chlorhexidine	69.59 ± 0.37	65.93 ± 0.56[*,b,E]	62.65 ± 0.56[*,b,E]
SonicFil 2	Deionised water	70.90 ± 0.74	69.71 ± 0.40[a,A]	69.89 ± 0.50[a,A]
	Povidone iodine	70.80 ± 0.40	62.87 ± 0.40[*,d,J]	59.34 ± 0.39[*,d,J]
	Hydrogen peroxide	70.92 ± 0.47	65.77 ± 0.20[*,c,I]	62.85 ± 0.65[*,c,I]
	Chlorhexidine	71.05 ± 0.90	68.14 ± 0.54[*,b,H]	65.85 ± 0.65[*,b,H]

[*] Indicates statistically significant difference (in rows) from before immersion (P < .05).
[a-d] Indicates statistically significant difference (in columns) for each material amongst the 4 storage agents (P < .05).
[A-M] Indicates statistically significant difference (in columns) amongst all groups (P < .05).

Table 4 – Mean surface roughness (± SD) of the different materials tested when immersed in various mouthwashes for different time periods

Material	Mouthwash	Mean surface roughness (μm) ± SD		
		Before immersion	7 days after immersion	14 days after immersion
Filtek	Deionised water	0.01 ± 0.01	0.02 ± 0.01[a,A]	0.02 ± 0.02[a,A]
Z350XT	Povidone iodine	0.01 ± 0.01	0.13 ± 0.03[*,d,D]	0.15 ± 0.02[*,d,D]
	Hydrogen peroxide	0.01 ± 0.01	0.11 ± 0.02[*,c,C]	0.13 ± 0.02[*,c,C]
	Chlorhexidine	0.01 ± 0.01	0.09 ± 0.02[*,b,B]	0.11 ± 0.02[*,b,B]
Premise	Deionised water	0.01 ± 0.01	0.02 ± 0.01[a,A]	0.02 ± 0.01[a,A]
	Povidone iodine	0.01 ± 0.01	0.33 ± 0.02[*,d,M]	0.36 ± 0.02[*,d,M]
	Hydrogen peroxide	0.01 ± 0.01	0.30 ± 0.02[*,c,L]	0.33 ± 0.02[*,c,L]
	Chlorhexidine	0.01 ± 0.01	0.28 ± 0.03[*,b,K]	0.30 ± 0.02[*,b,K]
Filtek One	Deionised water	0.01 ± 0.01	0.02 ± 0.01[a,A]	0.02 ± 0.01[a,A]
Bulk Fill	Povidone iodine	0.01 ± 0.01	0.19 ± 0.02[*,d,G]	0.22 ± 0.02[*,d,G]
Restorative	Hydrogen peroxide	0.01 ± 0.01	0.16 ± 0.01[*,c,F]	0.18 ± 0.02[*,c,F]
	Chlorhexidine	0.01 ± 0.01	0.14 ± 0.01[*,b,E]	0.16 ± 0.02[*,b,E]
SonicFil 2	Deionised water	0.01 ± 0.01	0.02 ± 0.01[a,A]	0.02 ± 0.01[a,A]
	Povidone iodine	0.01 ± 0.01	0.26 ± 0.01[*,d,J]	0.28 ± 0.02[*,d,J]
	Hydrogen peroxide	0.01 ± 0.01	0.23 ± 0.01[*,c,I]	0.25 ± 0.01[*,c,I]
	Chlorhexidine	0.01 ± 0.01	0.21 ± 0.02[*,b,H]	0.23 ± 0.02[*,b,H]

[*] Indicates statistically significant difference (in rows) from before immersion (P < .05).
[a-d] Indicates statistically significant difference (in columns) for each material amongst the 4 storage agents (P < .05).
[A-M] Indicates statistically significant difference (in columns) amongst all groups (P < .05).

composites evaluated, the most significant decrement in surface hardness, increment in roughness, and colour changes (ΔE*) were shown in Premise, followed by SonicFil 2, Filtek One Bulk Fill Restorative, and Filtek Z350 XT, respectively (P < .05).

Discussion

The experimental hypothesis of this study was that surface hardness, roughness, and colour values of resin composites tested would change after immersion in different mouthwashes. Based on the results of the present study, we failed to reject the null hypothesis. The present study showed that after 7 and 14 days of resin composites being tested and immersed in all mouthwashes, significant hardness decrement, roughness (Ra) increment, and colour change (ΔE*) were found (P < .05).

The disinfectant mouthwashes used in this study were based on mouthwashes that were given to patients to rinse their mouths before undergoing dental procedures during the COVID-19 pandemic. The mouthwashes were 0.2% povidone iodine, 1% hydrogen peroxide, and 0.12% chlorhexidine. The pH is a measurement of the amount of free hydrogen ions (H$^+$) in a solution. This indicates the ability to dissociate into the hydrogen ions of the solution. Titratable acidity or total

Table 5 – The colour changes (Mean ΔE* ± SD) of seven different evaluated dental materials immersed in various mouthwashes over different time periods

Material	Mouthwash	Mean difference of color change (ΔE* ± SD) of materials tested immersed in various mouthwashes		
		Before immersion − 7 days	7 − 14 days	Before immersion − 14 days
Filtek Z350XT	Deionised water	$1.17 \pm 0.06^{a,A}$	$0.97 \pm 0.07^{a,A}$	$1.34 \pm 0.06^{a,A}$
	Povidone iodine	$1.76 \pm 0.04^{d,D}$	$0.66 \pm 0.02^{d,D}$	$2.02 \pm 0.05^{d,D}$
	Hydrogen peroxide	$1.38 \pm 0.03^{c,C}$	$0.63 \pm 0.03^{c,C}$	$1.64 \pm 0.04^{c,C}$
	Chlorhexidine	$1.25 \pm 0.02^{b,B}$	$0.60 \pm 0.03^{b,B}$	$1.35 \pm 0.01^{b,B}$
Premise	Deionised water	$1.19 \pm 0.03^{a,A}$	$0.98 \pm 0.05^{a,A}$	$1.34 \pm 0.04^{a,A}$
	Povidone iodine	$2.15 \pm 0.13^{d,M}$	$1.31 \pm 0.01^{d,M}$	$2.71 \pm 0.02^{d,M}$
	Hydrogen peroxide	$2.04 \pm 0.06^{c,L}$	$0.86 \pm 0.05^{c,L}$	$2.57 \pm 0.06^{c,L}$
	Chlorhexidine	$1.32 \pm 0.02^{b,K}$	$0.80 \pm 0.01^{b,K}$	$1.43 \pm 0.03^{b,K}$
Filtek One Bulk Fill Restorative	Deionised water	$1.18 \pm 0.07^{a,A}$	$0.98 \pm 0.07^{a,A}$	$1.35 \pm 0.08^{a,A}$
	Povidone iodine	$1.80 \pm 0.02^{d,G}$	$1.07 \pm 0.09^{d,G}$	$2.30 \pm 0.03^{d,G}$
	Hydrogen peroxide	$1.44 \pm 0.05^{c,F}$	$0.73 \pm 0.05^{c,F}$	$2.01 \pm 0.09^{c,F}$
	Chlorhexidine	$1.29 \pm 0.01^{b,E}$	$0.69 \pm 0.04^{b,E}$	$1.37 \pm 0.02^{b,E}$
SonicFil 2	Deionised water	$1.19 \pm 0.02^{a,A}$	$0.97 \pm 0.05^{a,A}$	$1.35 \pm 0.02^{a,A}$
	Povidone iodine	$2.05 \pm 0.04^{d,J}$	$1.11 \pm 0.04^{d,J}$	$2.49 \pm 0.01^{d,J}$
	Hydrogen peroxide	$1.69 \pm 0.03^{c,I}$	$0.83 \pm 0.05^{c,I}$	$2.11 \pm 0.03^{c,I}$
	Chlorhexidine	$1.32 \pm 0.01^{b,H}$	$0.74 \pm 0.05^{b,H}$	$1.40 \pm 0.01^{b,H}$

a-d Indicates statistically significant difference (in columns) for each material amongst the 4 storage agents ($P < .05$).
A-M Indicates statistically significant difference (in columns) amongst all groups ($P < .05$).

acidity is a measurement of the total acid in a solution, which is an indicator of the amount of acid causing surface changes on the materials.[28,29] Titratable acidity is measured by titration with standard alkaline solutions or sodium hydroxide. If a large amount of sodium hydroxide solution is used, it indicates a large amount of acid. However, the pH and total acid content sometimes were not related. Therefore, the total acid content was also measured. The results of this study found that 0.2% povidone iodine used the greatest volume of sodium hydroxide solution for titration, which is in agreement with the results that povidone iodine caused the most significant decrease in surface hardness, increase in roughness, and the most colour changes in the resin composites.

Regarding surface roughness, all resin composites tested had increased roughness values after disinfectant mouthwash immersions. The acidity of the mouthwash caused polymer matrix decomposition of the resin composites[14,15] through hydrolysis of ester radicals in dimethacrylate monomers such as bisphenol A-glycidyl methacrylate, ethoxylatedbisphenol-A dimethacrylate, urethane dimethacrylate, and triethylene glycol dimethacrylate (TEGDMA)[18] causing fillers to easily extrude from the resin matrix. As a result, resin composite had a higher surface roughness. Resin composite with a small filler size has less surface roughness than that with a large filler size.[13] Therefore, Premise and SonicFil 2 had higher roughness values than Filtek One Bulk Fill Restorative and Filtek Z350XT after the immersion period due to Premise and SonicFil 2 having a larger filler size than Filtek One Bulk Fill Restorative and Filtek Z350XT, which is in agreement with Akalin et al.[8]

Regarding surface hardness, the 4 products of the resin composites showed a decrement in surface hardness. This resulted from the composition of mouthwashes that contain acids and the water absorption process. Acids in mouthwashes caused the remaining monomers from the reaction to be released from the resin matrix.[14−17] Also, resin composite materials have water absorption ability. Water molecules enter the material's network between the polymer chains through hydrolysis causing the polymer chains to break into monomers and oligomers, resulting in surface hardness decrement.[19,21] The amount of water absorption depends on the composition of the resin composite and the reaction between the resin and the filler.[8,20] SonicFil 2 bulk fill resin composite had a greater statistically significant decrease in surface hardness. This is due to the fact that Filtek One Bulk Fill Restorative has a smaller filler size than SonicFil 2. The small fillers have advantages in terms of gaps filling in the material, making the gaps in the material smaller. Materials with small fillers also allows for increased surface area between the fillers and the resin matrix. Thus, Filtek One Bulk Fill Restorative absorbed less water.

Regarding colour stability, the results of this study showed that the 4 resin composites tested showed colour changes after immersion in mouthwash. This is consistent with previous studies,[13,15] which have stated that the reasons for colour changes included hydrolysis of the resin matrix, contact with acidic agents, and the water-absorbing properties of the materials. Due to the composition of resin composite material, SonicFil 2 contains a TEGDMA resin matrix, which is a viscosity-reducing agent of resin composite containing a highly efficient ethoxy group for forming hydrogen bonds with water. Thus, TEGDMA contains matrix resin composites that have more water adsorption properties.[8] Colour changes by external factors represent the most important factor affecting colour stability and service life of resin composite restorations.[22] Using chlorhexidine mouthwash results in a brown stain on the tooth surface, resin composite restorations, and other restorations with other restorative materials.[11] From the present study, it was found that the 4 resin composite materials after immersion in 0.12% chlorhexidine had less colour change than 0.2% povidone iodine because the colour change from chlorhexidine often occurred with food or beverage consumption.[27] Hydrogen peroxide is currently used as a bleaching agent because free radicals produced by hydrogen peroxide can react with the polymer network of resin composite, causing the

material to change its colour. However, the concentrations of hydrogen peroxide used for bleaching are 6%, 10%, 16%, 22%, and 35%, which are higher than the concentrations used in the present study. It was also found that resin composite that undergoes the complete light polymerisation process is more resistant to reaction with hydrogen peroxide.[23] The specimen preparation in this study was polymerised for 40 seconds, and the overlapping area was polymerised 4 times per specimen to complete the polymerisation process. Therefore, the 1% hydrogen peroxide used in this study resulted in less colour change.

This experiment measured colour change using the CIE-LAB system. The CIELAB system is recommended for evaluating colour changes because it can assess even the slightest colour change and has the advantage of being able to measure repeatability and measurement sensitivity. The colour measurement used a white background, as for restoration procedures on a tooth cavity. In the present study, after 14 days of immersion, all resin composites tested had ΔE values of less than 3.3 but greater than 1, which indicated that it can be distinguished by the eye of the operators, which is considered clinically acceptable. The colour change of the material was due to the changes in the a* and b* values; in particular, the material changed its colour to more red and yellow after immersion in mouthwash. This change corresponded to colour characteristics of synthetic dyes that are constituents in mouthwash.

Currently, there are many types of tooth-coloured restorative materials to select from, and they have been developed to improve their properties such as strength, hardness, and wear resistance. However, the most significant finding in this experimental study was that the use of mouthwash before performing dental procedures in the novel COVID-19 epidemic (gargling for 1 minute and then spitting out) affected the resin composite restoration materials evaluated. These included increased surface roughness and colour changes and decreased surface hardness. As for clinical relevance, this study suggested that Filtek Z350 XT was the most appropriate restorative material for this task.

The results of this in vitro study are from simulated behaviour of using mouthwashes for COVID-19 transmission prevention before dental procedures. However, there are limitations related to the results of the present study. Both sides of specimens were immersed and exposed to the mouthwashes. In a clinical situation, restorative materials are bonded to the tooth cavity on one side, whilst only the other side of the restorative materials is exposed to the oral cavity. The oral cavity also imparts a various condition regarding temperature and pH changes. This might also influence the other properties of the restorative materials. Further studies might conduct in vivo research close to the actual oral cavity in order to achieve in vivo results, including testing various time periods, relating to various types of dental procedures to make possible results which clearly study the effect of mouthwash on resin composite restorative materials.

Conclusions

Considering the limitations of this current study, it was concluded that immersion in mouthwashes for COVID-19

transmission prevention increased surface roughness and colour changes and decreased surface hardness of the resin composites evaluated. Within the resin composite materials tested in this study, the greatest degradation was found in Premise after immersion in 0.2% povidone iodine.

Author contributions

Saijai Tanthanuch and Boonlert Kukiattrakoon: conception and design of the study, acquisition of data, and analysis and interpretation of data. Chailuck Naiyanart, Tanyanat Promtong, Panuwit Yothinwatthanabamrung, Suttida Pumpua: analysis and interpretation of data. Boonlert Kukiattrakoon: drafting the article or revising it critically for important intellectual content. All authors: final approval of the version to be submitted.

Conflict of interest

None disclosed.

Acknowledgements

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